UNCLASSIFIED

AD-A205 145

DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR-TR- 89-0102
6a. NAME OF PERFORMING ORGANIZATION Univ of Denver	6b. OFFICE SYMBOL (If applicable)
7a. NAME OF MONITORING ORGANIZATION AFOSR/NP	
6c. ADDRESS (City, State, and ZIP Code) P O Box 10127 Denver, CO 80208	7b. ADDRESS (City, State, and ZIP Code) Building 410, Bolling AFB DC 20332-6448
8a. NAME OF FUNDING/SPONSORING ORGANIZATION AFOSR	8b. OFFICE SYMBOL (If applicable) NP
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER AFOSR-83-0010	
8c. ADDRESS (City, State, and ZIP Code) Building 410, Bolling AFB DC 20332-6448	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
61102F	2311	A1	

11. TITLE (Include Security Classification)
(U) THEORETICAL MODELING OF PLASMA WAVES IN THE MAGNETOSPHERE

12. PERSONAL AUTHOR(S) Dr. V. L. Patel

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
FINAL	FROM 1 Oct 82 TO 30 Sep 88	October 1988	11

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
	04 01	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Theoretical studies of plasma waves play an important role in the understanding of characteristics of the problems of communications in the ionized environments of the earth. This project devoted efforts in the study of low frequency waves in the ionosphere and the magnetosphere. The aim was to include all recent attributes of the magnetospheric plasma, e.g. inhomogeneity, various ion species and finite beta effects in the theoretical modes. All of these features of the plasma medium affect the communication in various frequency ranges.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT X ☐ UNCLASSIFIED/UNLIMITED X ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL H R RADOSKI	22b. TELEPHONE (Include Area Code) (202) 767-4906 — 22c. OFFICE SYMBOL AFOSR/NP

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Final Report on AFSOR Grant 83-0010

Title: Theoretical Modeling of Plasma Waves in the Magnetosphere

Period: October 1, 1982 - September 30, 1988

Principal Investigator: Dr. V.L. Patel
Department of Physics
University of Denver
Denver, CO. 80208

Project Monitor: Dr. Henry Radoski

Research:

Theoretical studies of plasma waves play an important role in the understanding of characteristics of the problems of communications in the ionized environments of the earth. This project devoted efforts in the study of low frequency waves in the ionosphere and the magnetosphere. Our aim was to include all recent attributes of the magnetospheric plasma, e.g. inhomogeneity, various ion species and finite beta effects in the theoretical modes. All of these features of the plasma medium affect the communication in various frequency ranges. The main results of this project are described as follows:

1. Theoretical Models and Numerical Codes

A theorectical model based on Vlasov-Maxwell equations has been developed that incorporates the following characteristics of plasma and field environments: inhomogeneities in plasma density and temperature, plasma temperature anisotropy i.e. ratio of temperatures parallel and perpendicular to the ambient magnetic field, and multispecies ions with arbitrary Z number. The model includes high β effects in a systematic manner. Earlier work that included large β effects did not include correct effects of gradient B. We have accomplished inclusion of ∇B effects in a consistent manner (Ng and Patel, 1983). The model is valid for arbitrary β and Larmor radius parameter b_i. The dispersion relation obtained can be applied in any plasma system in space. However, the analytical solution of the dispersion relation is almost impossible. So, the model includes main observed characteristics of space plasma i.e. inhomogeneities, multispecies, finite temperature and kinetic effects, etc. But the solution must be obtained by numerical methods.

The numerical codes were developed to obtain results for coupled drift-compressional and shear Alfvén modes for various parameters appropriate to the magnetospheric plasma. A formula for the coupling factor between the modes has been obtained. The important result from these studies is that the high phase velocity compression mode ($\omega/k_\parallel >> v_{\parallel i}$) has insignificant coupling to shear Alfvén waves, while the low phase velocity ($\omega/k_\parallel < v_{\parallel i}$) has strong coupling (Ng and Patel, 1983).

The Vlasov-Maxwell kinetic model has certain limitations. The field geometry is usually assumed of slab geometry (or some variations in it) so that orbit integration can be performed easily. A gyrokinetic model based on work of Catto et al. (1981)

and Berk et al. (1983) has been adopted so that any arbitrary field geometry (including a dipole field) can be used. We have completed analytical formalism appropriate for the magnetospheric problem. The results have been presented at the annual AGU meetings. Numerical work has been done on a compressional mode and the results were published in the JGR (Ng, Patel, Chen, 1984). A theoretical model proposed by Radoski (1971) was modified to include finite conductivity boundary conditions at the ionosphere. The coupled equations of MHD waves were solved by using the Finite Element Method (FEM). The eigenvalues and eigenfrequencies were calculated by using FEM for the coupled mode. This is the first time this untractable problem has been subjected to numerical analysis. The results will be published in JGR (Krauss-Varban and Patel, 1988).

2. Source Mechanisms

The theoretical modeling assumes that the source energy which drives the waves is obtained from gradients of temperature and density or the temperature anisotropy. The energy to drive waves is also available from the non-Maxwellian distribution functions e.g. loss-cone, anisotropic velocities, and beams. In laboratory and space plasma study of electron beams, driving instabilities have been studied extensively. The ion beams can be very important in fusion problems and in space plasma. In space, presence of ion beams in boundary layers and the magnetospheric tail have been detected by spacecrafts (e.g. ISEE2 observations by Candidi et al., 1984). The theoretical work with respect to generation mechanism for the low frquency waves in the magnetospheric plasma is needed. We have studied one aspect of ion beam instability. The waves with $\omega < \Omega_{ci}$ have been studied for electromagnetic mode, in the presence of gyrating ion beams. The calculations of growth rates for waves propagating at various angles with respect to the magnetic field were made. The analytical formalism has been developed in a general form so that the beams propagating at an angle to the ambient field can be studied by retaining gyrating ion effect. The formalism also allows study of waves propagating obliquely with respect to the magnetic field. The results are published in JGR (Sharma and Patel, 1986).

A theoretical model of Kelvin-Helmholtz instability was studied by using the CGL approach, and numerical calculations were carried out for the magnetospheric boundary (Choudhury and Patel, Phys. Fluids, 1985).

3. Nonlinear Problems

The linear theory provides a basic understanding of the physical processes. However, the most physical phenomena eventually tends to stable parameters through nonlinear saturation mechanisms. We have studied nonlinear Alfvén waves by deriving a nonlinear Schrodinger equation for space plasma. The solution of NSL was tested by using magnetic field observations from the geocentric satellites of the GOES series. The results were published in Physica D. (Patel and Dasgupta, 1987).

Parametric instability has been studied and nonlinear coupling of the wave has been studied. The excitation of the plasma waves are possible by conversion of energy from the frequency regime. The Alfvén waves can be excited by the ion cyclotron waves by down conversion (Patel et al., 1985). The up conversion of lower hybrid waves with ion beams and simulated Raman effect with electron beam has been studied. The results are published in Phys. Fluids (Sharma amd Patel, 1985). The filamentation instability has been studied for the propagation of the VLF waves in the magnetosphere. The results are published in Phys. Fluids (Sharma and Patel, 1985) and Planetary Space Science (Patel and Tripathi, 1988).

4. Research Publications

The results summarized in sections 1 to 3 were published in the following refereed journals, reprints of which are enclosed:

"The Coupling of Shear Alfvén and Compressional Waves in High Beta Plasma," J. Geophys. Res., 88, 10,035, 1983.

"Drift Compressional Instability in the Magnetosphere," J. Geophys. Res., 89, 10763, 1984.

"Parametric Excitation of Shear Alfvén modes by Electrostatic Ion Cyclotron Waves in the Magnetosphere," J. Goephysical Res., 90, 9590, 1985.